A MACHINE AND METHOD FOR PRODUCING POROUS MEMBRANES FOR MEDICAL USE

BACKGROUND OF THE INVENTION

The present invention relates to a machine and method for producing porous membranes for medical use.

In particular, the present invention relates to a machine and method for producing biocompatible and heamocompatible membranes designed to constitute vascular prostheses and artificial tissues for medical use.

The prior art describes many techniques for the production, using polymers, of small-diameter porous or filamentous tubular tissues.

In addition to the now consolidated production techniques using extrusion, a spray method for producing membranes is known, by which they are obtained, for example, from thermodynamically unstable polymeric solutions. Specifically, the unstable solution is generated with the addition of a non-solvent to a dilute polymeric solution and the membranes are obtained with spray deposition, using a single spray means, or with simultaneous but separate

spray deposition of the unstable polymeric and non-solvent solution by separate spray means, on a supporting element designed to define the shape of the membrane.

The method described above allows the production, for example, of small-diameter vascular prostheses or flat membranes obtained by cutting tubular membranes with a larger diameter longitudinally.

The vascular prostheses or flat membranes, hereinafter generally referred to as porous membranes, obtained with the above-mentioned techniques, although having indisputable positive aspects, are not free of disadvantages.

The main disadvantage consists of the fact that the chemico-physical properties of the porous membranes obtained with the spray method, particularly the porosity of the membrane structure, are difficult to control.

Generally speaking, with the known methods, it is difficult to obtain membranes able to simultaneously fulfil haemocompatibility and biocompatibility requirements and provide adequate mechanical strength.

SUMMARY OF THE INVENTION

Therefore, the aim of the present invention is to provide a machine for producing porous membranes which

are free of the above-mentioned disadvantage and, at the same time, are practical for use and simple and economical to produce.

Accordingly the present invention provides a machine for producing porous membranes for medical use as described in claim 1.

Another aim of the present invention is to provide a method for producing membranes for medical use, in particular tubular membranes, which can be used as prostheses, especially vascular prostheses, and more specifically small-diameter vascular prostheses, the method being simple and flexible to implement.

Accordingly the present invention also provides a method for producing porous membranes for medical use as described in claim 16.

BRIEF DESCRIPTION OF THE DRAWINGS

The technical features of the present invention, in accordance with the above-mentioned aims, are set out in the claims herein and the advantages more clearly illustrated in the detailed description which follows, with reference to the accompanying drawings, which illustrate a preferred embodiment of the invention without limiting the scope of the inventive concept, and in which:

Figure 1 is a schematic illustration of a preferred

embodiment of a machine for producing porous membranes, made in accordance with the present invention;

Figure 2 is a top perspective view of a machine for producing membranes, made in accordance with the present invention;

Figures 3, 4, 5 and 6 are front elevation views of a portion of the machine illustrated in Figure 2 in as many different operating configurations;

Figures 7, 8 and 9 are top plan views of a portion of the machine illustrated in Figures 1 and 2 in as many different operating configurations;

Figure 10 is an enlarged cross-section of the detail P illustrated in Figure 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to Figure 2, the numeral 1 indicates as a whole a portion of a machine for producing porous membranes 2 made in accordance with the present invention.

The machine 1 comprises a frame 3 and a central body 4 extending longitudinally in a direction D.

The central body 4 has a first and a second spindle 5, 6 which are coaxial with one another, driven in synchronized rotation about an axis A parallel with the direction D, by respective toothed belts 7, 8.

The toothed belts 7, 8 are in turn driven by

toothed pulleys, of which Figure 2 fully illustrates only one, labeled 9, keyed to opposite ends of a shaft 10. The shaft 10 is turned by drive means of the known type which are not illustrated or described in any further detail.

The shaft 10 has an axis of rotation B parallel with the above-mentioned axis A of the spindles 5, 6.

Each spindle 5, 6 supports one end of a supporting element 11. In Figure 2 the supporting element 11 consists of a cylindrical body 12 with a small diameter.

At the side of the central body 4, the machine 1 comprises a first carriage 13 which slides longitudinally in the direction D, on guide parts 14. A threaded rod 15 engages as it turns with the carriage 13, to drive the carriage in the direction D. The threaded rod 15 is turned by drive means of the known type and not illustrated.

With reference to Figures 1 and 2, the first carriage 13 comprises first and second guns 16, 17 with nozzles 16a, 17a designed to spray fluid substances, respectively consisting of first and second mixtures 18, 19.

The mixtures 18 and 19 are supplied to the guns 16, 17 through pipes 20 by pumps 21, 22.

The mixtures 18, 19 are formed at and by mixer

parts 23, 24 to which a plurality of stored reserves of components designed to form the above-mentioned mixtures 18, 19 are fluidly connected.

In particular, for example Figure 1 illustrates three reserves 25a, 25b, 25c of components 18a, 18b, 18c for the first mixture 18 and three reserves 26a, 26b, 26c of components 19a, 19b, 19c for the second mixture 19.

The machine 1 also comprises a source 27 of pressurized gas supplied to the guns 16, 17 by pipes 28 to activate the nozzles 16a, 17a for spray emission of the mixtures 18, 19.

The nozzles 16a, 17a of the two guns 16, 17 are angled in such a way that they substantially converge on the same point of the cylindrical body 12.

With reference to Figure 2, on the side of the cylindrical body 12 opposite the first carriage 13, the machine 1 comprises a second carriage 29 which also slides longitudinally in the direction D on respective guide parts 30 and is driven by a threaded rod 15.

The second carriage 29 is covered by an extractor hood 31, one of whose intakes 32 is positioned over the guns 16, 17.

As shown in Figure 1, the hood 31 is connected, by a manifold schematically illustrated with a line 33, to a suction source, also schematically illustrated with a

block 34.

Again with reference to Figure 1, the machine 1 also comprises a central control unit 35 designed to act on the above-mentioned mixer parts 23, 24 as well as the guns 16, 17 and on the drive means of the spindles 5, 6 and carriages 13, 29.

The guns 16, 17, together with the nozzles 16a, 17a, the source 27 of pressurized gas and the pumps 21, 22 as a whole define, for the machine 1, means 36 for spraying the mixtures 18, 19.

In practice, as illustrated in Figure 2, the cylindrical body 12 is mounted on the central body 4 of the machine 1, with its ends 12a, 12b fixed to the respective spindles 5, 6.

Through the above-mentioned drive means, which are not illustrated, by means of the shaft 10 and belts 7, 8, the cylindrical body 12 which forms the supporting element 11 is turned about its axis A.

Starting with a first limit position of the first carriage 13, illustrated in Figure 2, the first nozzle 16a is activated by a flow of pressurized gas from the source 27 through the pipe 28. The pressurized gas, in accordance with known methods which are not described in any further detail, causes the spray emission of the first mixture 18 from the nozzle 16a, creating a first jet 16b. The first mixture is supplied to the nozzle

16a by the first pump 21 through the pipe 20.

The first pump 21 sends the first mixture 18 to the first nozzle 16a, drawing it from the first mixer 23 to which the three reserves 25a, 25b, 25c of the components 18a, 18b, 18c are connected.

Similarly to the above description with reference to the first nozzle 16a, and substantially simultaneously with this, the second nozzle 17a is also activated by a flow of pressurized gas from the source 27, through the pipe 28. The pressurized gas causes the spray emission of the second mixture 19 from the nozzle 17a, creating a second jet 17b. The second mixture 19 is supplied to the nozzle 17a by the second pump 22 through the pipe 20.

The second pump 22 sends the second mixture 19 to the second nozzle 17a, picking it up from the second mixer 24, to which the three reserves 26a, 26b, 26c of the components 19a, 19b, 19c are connected.

Again starting from the limit position illustrated in Figure 2, the first carriage 13 begins to move, driven by the rotation of the threaded rod 15 which as it turns engages with the carriage 13, in the direction D, as indicated by the arrow F1. At the same time, the cylindrical body 12 which constitutes the supporting element 11 is turned by the spindles 5, 6 about the axis A.

Similarly to the above description, the second carriage 29 begins to move, in the direction D as indicated by the arrow F1, driven by the rotation of the threaded rod 15 which as it turns engages with the carriage 29.

The extractor hood 31, integral with the second carriage 29 also moves in the direction D as indicated by the arrow F1, substantially synchronized with the first carriage 13 and remains over the nozzles 16a, 17a. The extractor action of the hood 31 is mainly intended to promote the regular emission of the jets 16b, 17b of the mixtures 18, 19 directed onto the supporting element 11.

The above-mentioned movements, simultaneously with the spraying action of the nozzles 16a, 17a, allows the fluid substances consisting of the mixtures 18, 19 to be deposited on the supporting element 11, the latter therefore constituting an element 37 on which the fluid substances are deposited and build up.

While the supporting element 11 carries on rotating about its own axis A continuously, the movement of the carriages in the direction D continues with an alternating motion. That is to say, when a second, opposite limit position, not illustrated and defined by the desired longitudinal dimensions for the membrane 2 being formed is reached, the direction of carriage 13,

29 movement is inverted and the movement continues in the direction indicated by the arrow F2.

The repetition in succession of numerous cycles of alternating carriage 13, 29 movement allows a given amount of the mixtures 18, 19 to be deposited, said amount designed to form the body of the membrane 2.

In other words, according to the desired thickness of the membrane 2 and considering the mixture fluid flow rate of nozzles 16b, 17b, the number of alternating motion feed cycles for the carriages 13, 29 is established.

A first set of such feed cycles is performed by the machine 1 with the mixtures 18, 19 having respective first compositions given by particular relative quantities for mixing of the components 18a, 18b, 18c, 19a, 19b, 19c stored in the reserves 25a, 25b, 25c, 26a, 26b, 26c.

The values required of these first compositions are set on the central control unit 35 which operates directly on the mixer parts 23, 24 in order to make up the first compositions.

As illustrated in Figure 10, the mixtures 18, 19 in their first configurations form a first layer 38 of the porous membrane 2, this first layer 38 having predetermined chemico-physical properties.

When executing the commands set on it, the central

control unit 35 therefore acts on the mixer parts 23, 24 to change the relative quantities of the components 18a, 18b, 18c, 19a, 19b, 19c stored in the reserves 25a, 25b, 25c, 26a, 26b, 26c and to create the second compositions of the mixtures 18, 19.

The machine 1 performs a second set of cycles with the mixtures 18, 19 with the second compositions.

As they are deposited on the first layer 38, the mixtures 18 and 19, in their second compositions, create a second layer 39 of the porous membrane 2, this second layer 39 having predetermined chemico-physical properties which are different to those of the first layer 38 below it.

In particular, as illustrated in Figure 10, these chemico-physical properties include the porosity of the membrane 2 which, for example with reference to tubular membranes for vascular prostheses, advantageously involves two different layers, the first, internal layer 38 in contact with the hematic fluid and more porous, and the second, external layer 39, more compact and with greater mechanical strength.

Advantageously, the mixers 23, 24, not illustrated in detail, are of the solenoid valve type, programmable and allow sequential valve opening so that the nozzles 16a, 17a can be supplied with predetermined quantities of the components 18a, 18b, 18c in the reserves 25a,

25b, 25c and, at the same time, the components 19a, 19b, 19c in the reserves 26a, 26b, 26c.

As illustrated in Figure 3, the element 37 on which the substances are deposited and build up is the cylindrical body 12 described above with reference to Figure 2, designed for producing tubular porous membranes 2 suitable for use as vascular prostheses even with very small diameters. The ends of the cylindrical body 12, not illustrated, are connected to the machine 1 spindles 5, 6 to turn about its axis A.

With reference to Figure 4, the element 37 on which the substances are deposited and build up consists of a cylindrical drum 12c with a diameter larger than that of the above-mentioned cylindrical body 12. Use of the drum 12c as an element 37 on which the substances are deposited and build up is intended to produce flat porous membranes obtained by cutting tubular membranes 2 produced with the above-mentioned method longitudinally.

With reference to Figure 5, the element 37 on which the sprayed fluid substances are deposited and build up consists of a stent 40. The stent 40 is a tubular element, made of metal or plastic for insertion, for example, in a blood vessel to hold it open and prevent constriction or pressure from the outside. The stent 40 is supported by a fine supporting wire 41,

advantageously made of polytetrafluoroethylene, which passes inside it and whose opposite ends, not illustrated in the drawing, are connected to the machine 1 spindles 5, 6 to turn about its axis A. As it turns about the axis A, the wire 41 causes the stent 40 to rotate.

During normal machine 1 operation, the stent 40 is hit by one or both of the jets 16b, 17b from the nozzles 16, 17 and, by means of the above-mentioned technique, a dense membrane 2 is formed on its surface, where the term dense refers to a membrane 2 whose porosity is very low, that is to say, which is substantially closed and impermeable. Since stents are tubular elements with gaps in the surface, the fluid substances sprayed can advantageously be deposited evenly on both the outer surface and in the inner tubular face, passing through the gaps in the outer surface.

Figure 6 illustrates a preferred embodiment of the configuration illustrated in Figure 5. In this improved configuration, the machine 1 comprises a heating element 46, schematically illustrated in the drawing. This element 46 is located below the stent 40 which is mounted on the supporting wire 41. The heating element 46 is regulated by a temperature control unit 47 and powered by known means, not illustrated or described in

further detail, for heating a zone 48 close to the stent 40.

Advantageously, thanks to the heat, when the particles of fluid substances sprayed by the nozzles 16a, 17a make contact with the stent 40, they form a substantially smooth and even layer on its surface. Moreover, the higher temperature created in the zone 48 by the presence of the heating element 46 allows the solvents present in the fluids sprayed to rapidly evaporate, increasing adhesion to the stent 40 by the membrane 2 as it is formed.

Figure 7 illustrates an alternative embodiment of the machine 1 disclosed. This alternative embodiment allows the above-mentioned procedure for spray depositing the fluid substances to be performed at the same time as a filament 42 of a suitable strengthening material (polyester, polyurethane, silicone, etc.) is wound around the supporting element 11. In particular, the filament 42 is incorporated in the porous membrane 2 being formed on the rotating cylindrical body 12. The filament 42 is wound in a spiral, with a predetermined pitch, by the respective movements of the rotating support 12 and of a rotary dispenser element 43 for the filament 42. The element 43 can slide in the direction D, driven by drive means which are not illustrated.

Figures 8 and 9 illustrate yet another embodiment

of the machine 1 disclosed. In this embodiment, once the nozzles 16 and 17 have deposited a predetermined quantity of the fluid substances on the cylindrical body 12, providing a given porous membrane 2 thickness, a tubular strengthening mesh 44 is inserted on the cylindrical body 12. The mesh 44, advantageously made of polyester, is then covered with another material, which may or may not be porous, again deposited with the spray technique described above. Advantageously, the tubular mesh 44 has substantially wide links, allowing substantial continuity between the material spray-deposited before insertion of the mesh 44 and that deposited over the mesh 44.

Therefore, the mesh 44 is incorporated between two polymeric layers.

Where special needs require it, the tubular mesh 44 can also only be coated on its outer wall, by inserting the mesh 44 directly on the cylindrical body 12 without previously spray-depositing any material on the body 12, as described above.

The strengthening filament 42 and the tubular mesh 44 together constitute membrane 2 stiffening elements 45.

The operations described above with reference to Figures 7, 8 and 9 may also be performed with large deposit and build up elements 37, such as the

cylindrical drum 12c, to obtain strengthened flat porous membranes 2.

Advantageously, depending on the required membrane 2 composition, the control unit 35 acts upon the mixer parts 23, 24, altering the relative quantities of components 18a, 18b, 18c, 19a, 19b, 19c, for example, in a substantially instantaneous way, with a stepped function, or continuously with a gradual function.

Advantageously, but without limiting the scope of the present invention, in a preferred embodiment of the present invention the first mixture 18 comprises a polymer and the second mixture 19 comprises a non-solvent for the polymer.

The invention described can be subject to modifications and variations without thereby departing from the scope of the inventive concept. Moreover, all the details of the invention may be substituted by technically equivalent elements.